Networking and Information Technology Research and Development: Scientific and Technical Aspects

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Director

National Coordination Office for

Information Technology Research and Development

Federal Networking & IT Research Opportunities FY 2004

October 2, 2003

The Federal government plays a critical role in supporting fundamental research in networking and IT
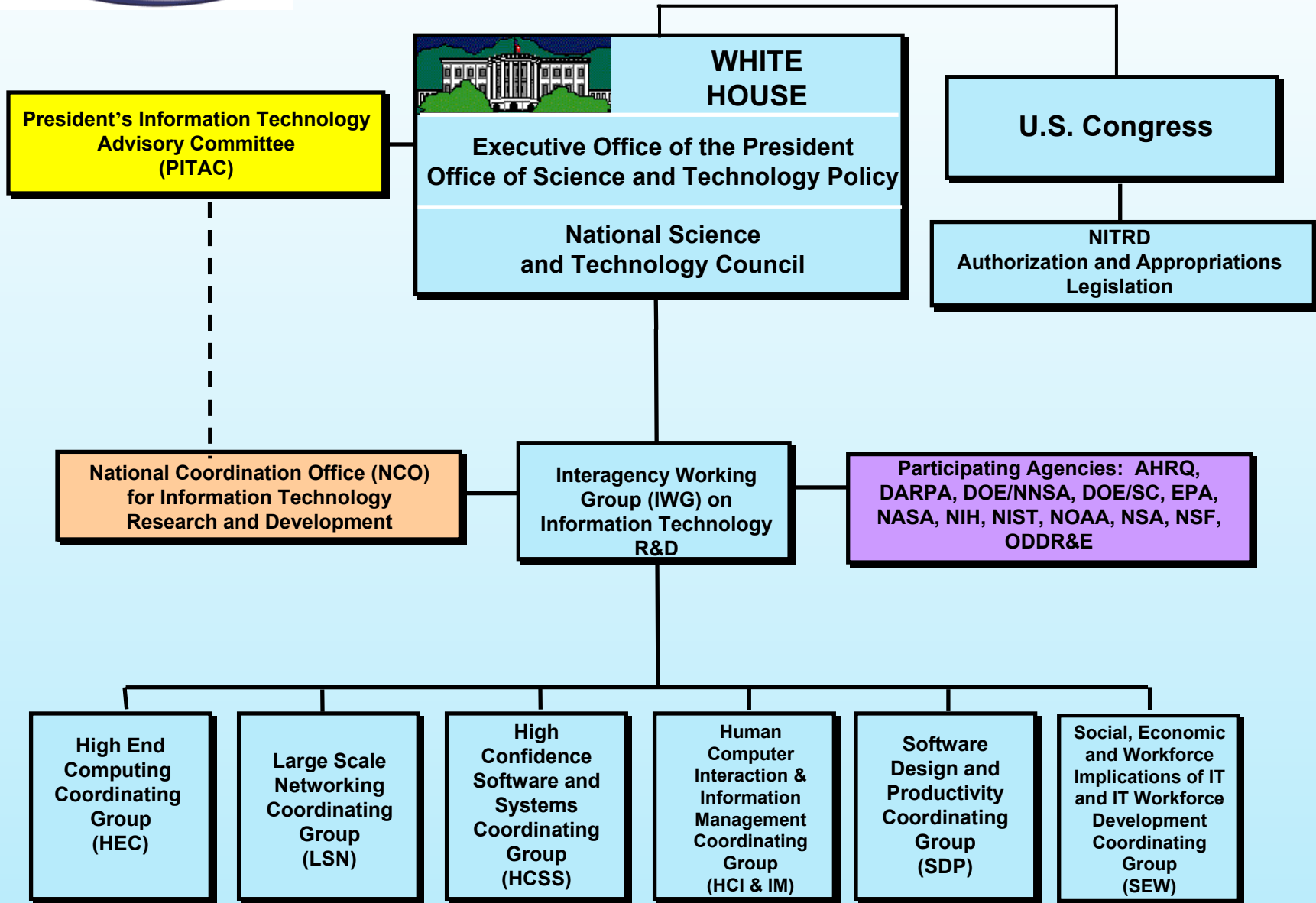
- Federally-sponsored research builds the technology base on which the information technology industry has grown
- Federal government funds basic research not funded by industry
  - High risk, innovative ideas whose practical benefits may take years to demonstrate
- Networking and Information Technology R&D program (NITRD) helps focus interagency IT R&D:
  - Identify common research needs
  - Plan inter-agency research programs
  - Coordinate and collaborate on research announcements and funding
  - Review research results and adjust accordingly
- NITRD evolved from the Federal High Performance Computing and Communications Initiative (HPCC), Computing Information and Communications Program (CIC), and Next Generation Internet Program (NGI)
- NITRD assessed by the President's Information Technology Advisory Committee

- Department of Defense
  - Defense Advanced Research Projects Agency (DARPA)
  - Defense Information Systems Agency (DISA)
  - National Security Agency (NSA)
  - Office of the Director of Defense Research and Engineering (ODDR&E)
- Department of Energy
  - Office of Science (DOE/SC)
  - National Nuclear Security Administration (DOE/NNSA)
- Department of Health and Human Services
  - National Institutes of Health (NIH)
  - Agency for Health Research and Quality (AHRQ)
- Department of Commerce
  - National Institute of Standards and Technology (NIST)
  - National Oceanic and Atmospheric Administration (NOAA)
- National Science Foundation (NSF)
- National Aeronautics and Space Administration (NASA)
- Environmental Protection Agency (EPA)
- Observer: Federal Aviation Administration (FAA)

NITRD Program Coordination

President's Information Technology Advisory Committee (PITAC)

WHITE HOUSE

Executive Office of the President Office of Science and Technology Policy

National Science and Technology Council

U.S. Congress

NITRD Authorization and Appropriations Legislation

National Coordination Office (NCO) for Information Technology Research and Development

Interagency Working Group (IWG) on Information Technology R&D

Participating Agencies: AHRQ, DARPA, DOE/NNSA, DOE/SC, EPA, NASA, NIH, NIST, NOAA, NSA, NSF, ODDR&E

High End Computing Coordinating Group (HEC)

Large Scale Networking Coordinating Group (LSN)

High Confidence Software and Systems Coordinating Group (HCSS)

Human Computer Interaction & Information Management Coordinating Group (HCI & IM)

Software Design and Productivity Coordinating Group (SDP)

Social, Economic and Workforce Implications of IT and IT Workforce Development Coordinating Group (SEW)

# FY 2003 NITRD Budgets

Agency	High End Computing Infrastruc. & Apps	High End Computing R & D	Human Computer Interaction & Info. Mgment	Large Scale Networking	Software Design & Productivity	High Confidence Software & Systems	Social Economic and Workforce
NSF	211.7	76.0	128.8	109.0	53.4	63.8	65.9
NIH	77.1	37.8	93.1	128.8	6.8	3.7	12.1
NASA	35.2	26.0	40.8	12.6	55.8	34.7	4.2
DARPA		109.8	42.9	17.6	58.6	3.2	
DOE/SC	98.4	37.3	16.2	28.7			3.5
HHS/AHRQ			6.4	5.2			
NSA		51.3		2.1		28.1	
NIST	3.5		6.2	3.2	7.5	2.0	
NOAA	13.5	1.8	0.5	2.8	1.5		
EPA	1.6		0.2				
ODDR&E		3.6	2.0	4.7	1.0	0.7	
DOE/NNSA	40.5	37.5			13.5	31.3	4.4
DoD/DISA						6.1	
TOTALS	481.5	381.1	337.1	328.2	215.9	142.3	90.1

- **High-End Computing: leading edge of high performance computing**

- **FY03 Focus: New plan for high-end computing research, resources, and acquisition (High-End Computing Revitalization Task Force)**

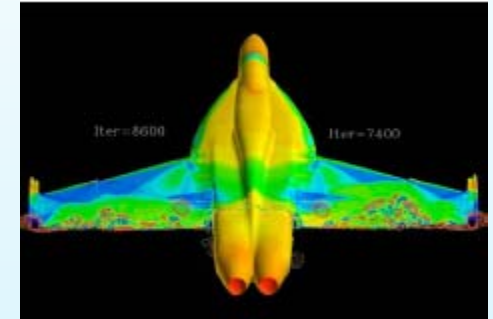- **Workshop on the Roadmap for the Revitalization of HEC organized by Computing Research Association http://www.cra.org/Activities/workshops/nitrd/**

Applications of High-End Computing:
Big Problems with Big Impacts
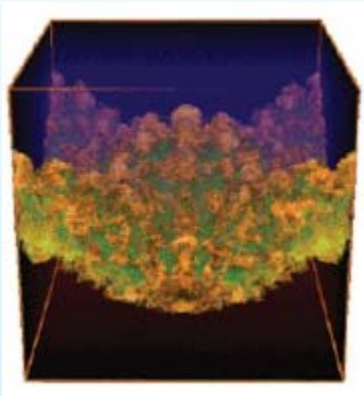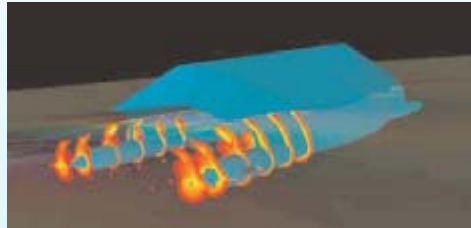
Ship Design

Aeronautics

Nuclear Stockpile Stewardship
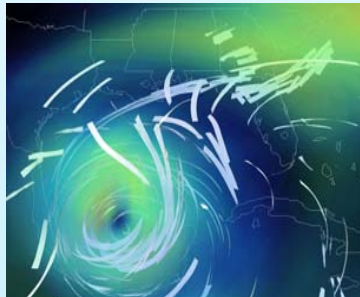
Weather Prediction

Cryptography
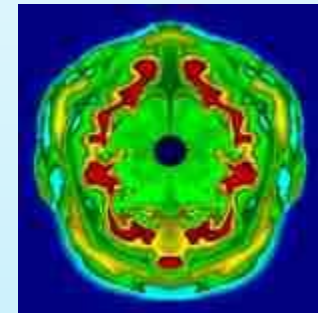
Astrophysical Simulation
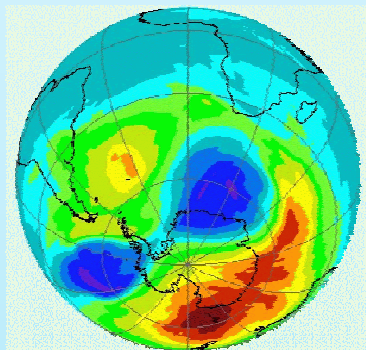
Climate Modeling

Nano-Science

Biology

7
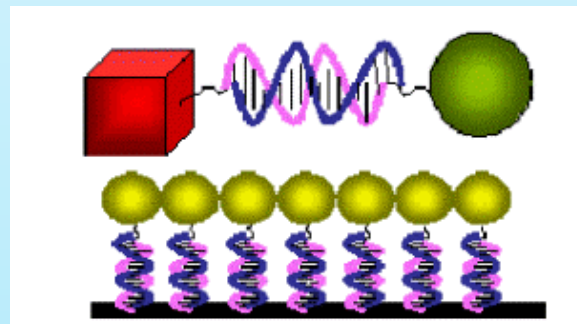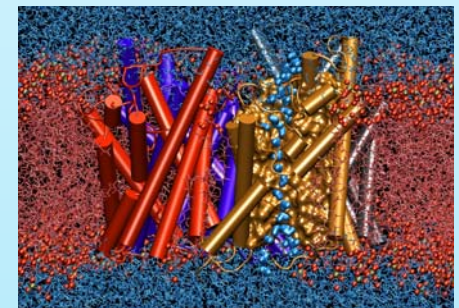
- **HEC solves problems with major impact on society and Government that cannot otherwise be solved**
  - HEC R&D, HEC computing must be driven by application needs

- **Current systems**
  - Hard to use
  - Enable us to do "old science" well, but not the new science we need

- **Mission requirements and scientific leadership require radical improvements in _time-to-solution_**

- **Inadequate resources – both capacity and capability**

- **Revitalize U.S. leadership in high-end computing as a key tool for science and technology.**
  - Make high-end computing easier and more productive to use
  - Make high-end computing readily available to Federally funded missions that need it
  - Sustain the development of new generations of high-end computing systems
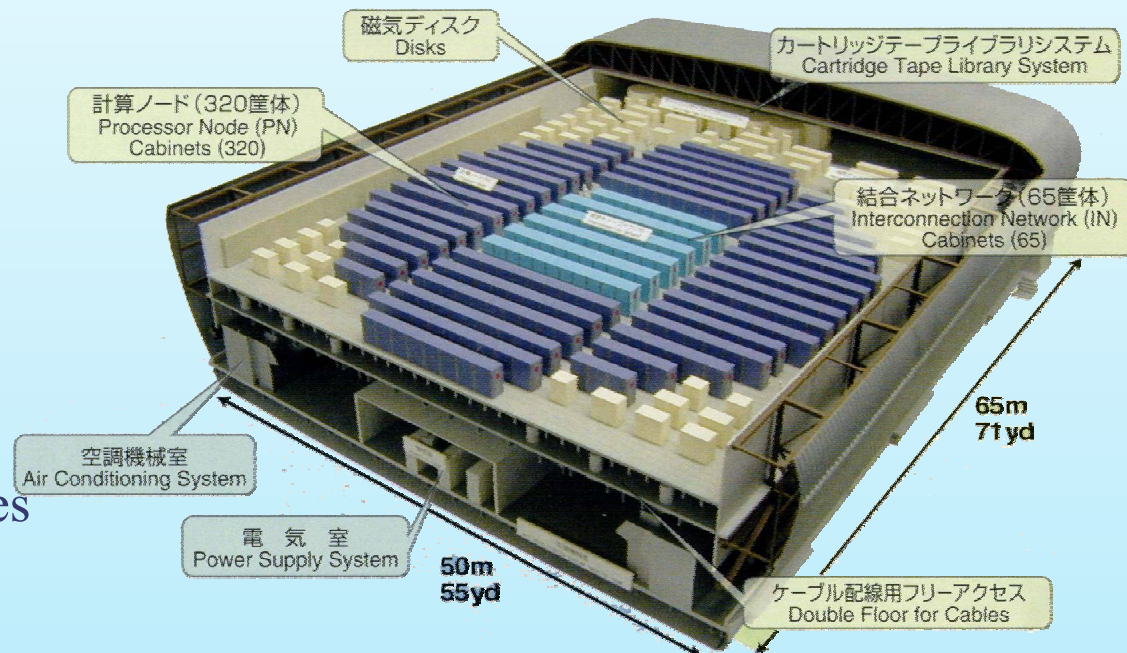 - Effectively manage and coordinate Federal high-end computing
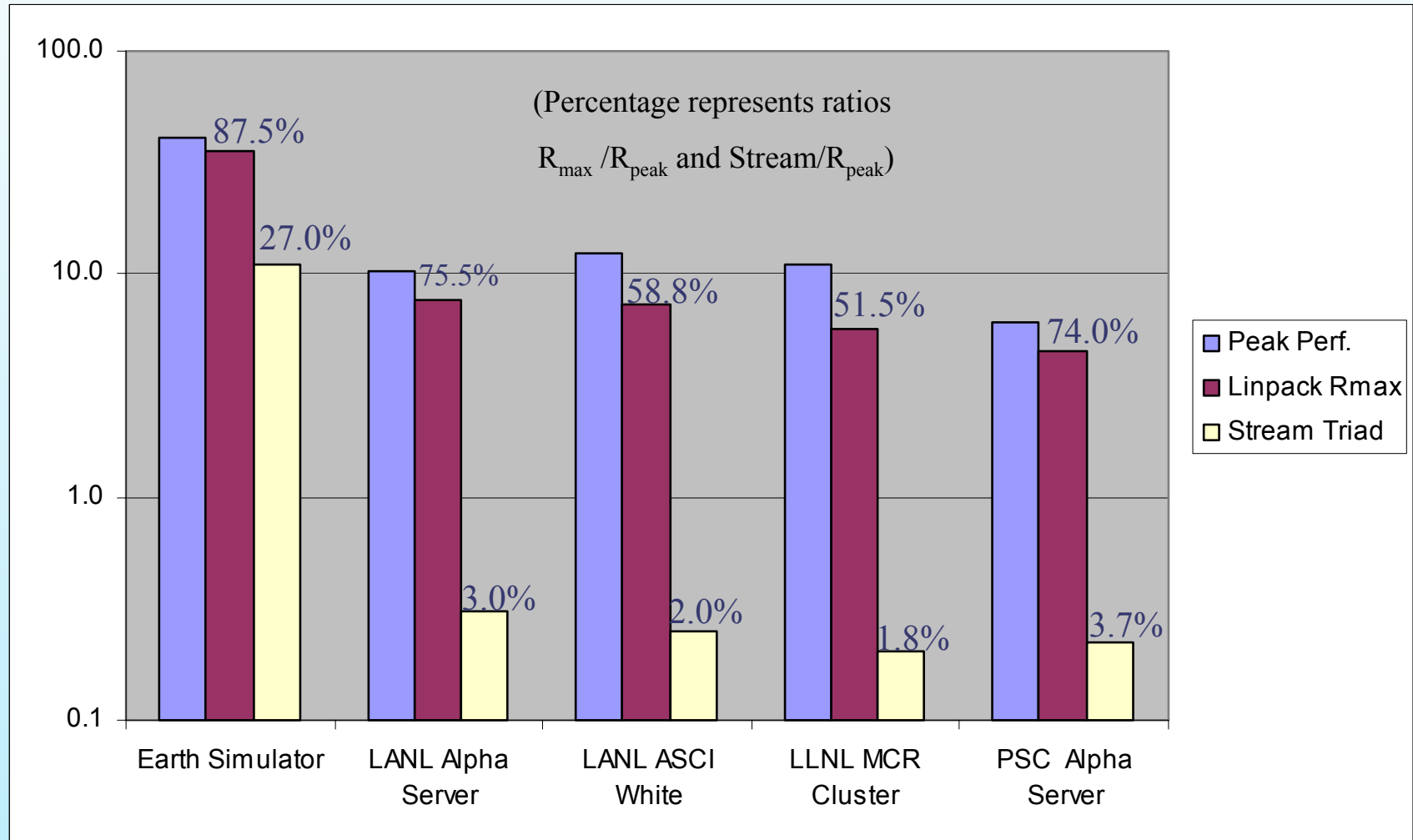
Japanese Earth Simulator

- **Japanese Earth Simulator entered service March 2002.**
  - **Took the #1 spot on the TOP500 Supercomputer list**
  - **Helped inspire a new look at U.S. high-end computing**
- **What it was:**
  - **A multi-agency cooperative research project**
  - **A well-designed, well-engineered, and very expensive computer based on proven technology**
  - **An attention-getting event that elevated the prominence of what was already considered to be an important issue.**
  - **A challenge that provided added incentive for action**
  - **A reminder that U.S. high-end computing planning was not as well coordinated as it should have been**
- **What it wasn't:**
  - **A technology surprise or revelation.**
  - **Demonstrated loss of U.S. scientific leadership**

Earth Simulator Has Inspired a New Look at U.S. High End Computing

- Based on the NEC SX architecture - 640 nodes, each node with 8 vector processors (8 GFlop/s peak per processor), 2 ns cycle time, 16GB shared memory
  - Total of 5120 total processors, 40 TFlop/s peak, and 10.24 TB memory

- Interconnect via single stage crossbar switch (1800 miles of cable), 83,000 copper cables, 16GB/s cross section bandwidth

- 700 TB disk space

- 1.6 PB mass store

- Area of computer = 4 tennis courts, 3 floors

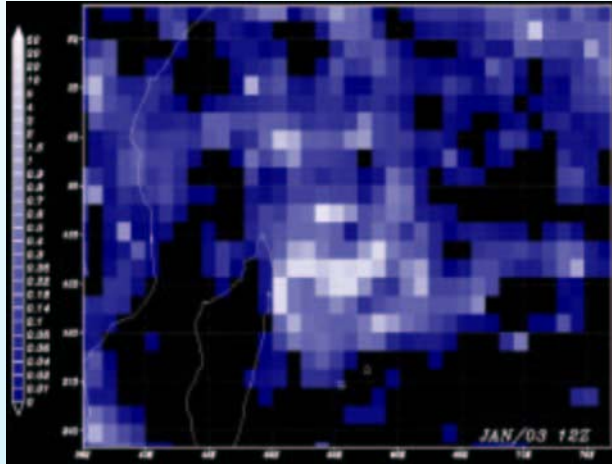- Highly efficient for climate and weather codes
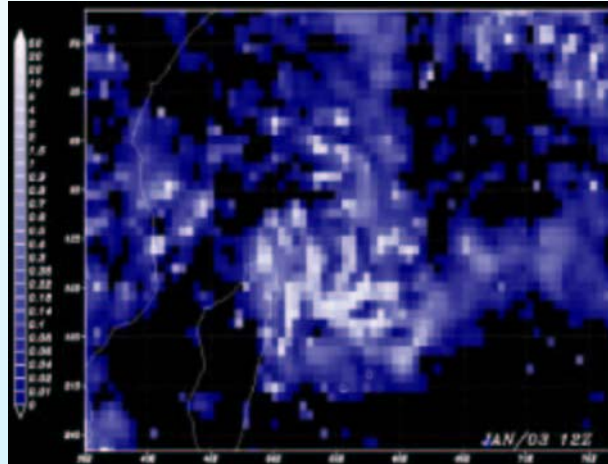
Power of Japanese Earth Simulator Allows Better Resolution of Local Features
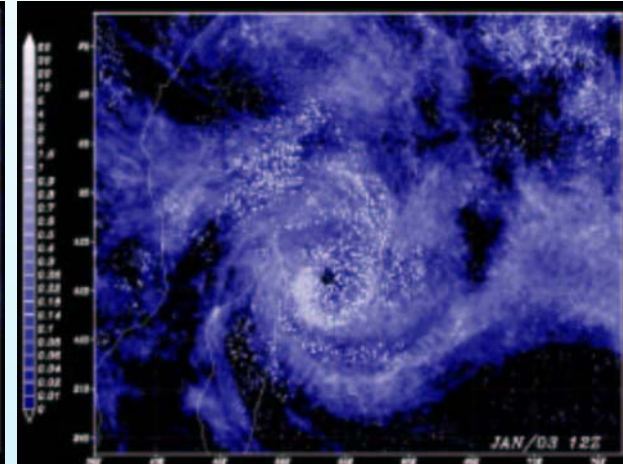
Simulation of Tropical Cyclone Near Madagascar

125.1 km grid   62.5 km grid   10.4 km grid

Explosion of a Super-Nova (not to scale) (DOE)
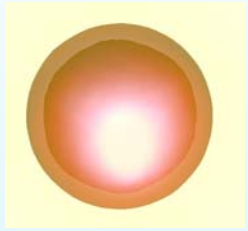
Start
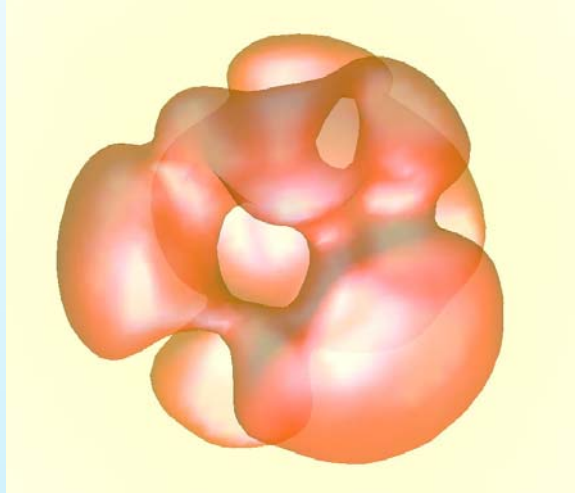
Middle
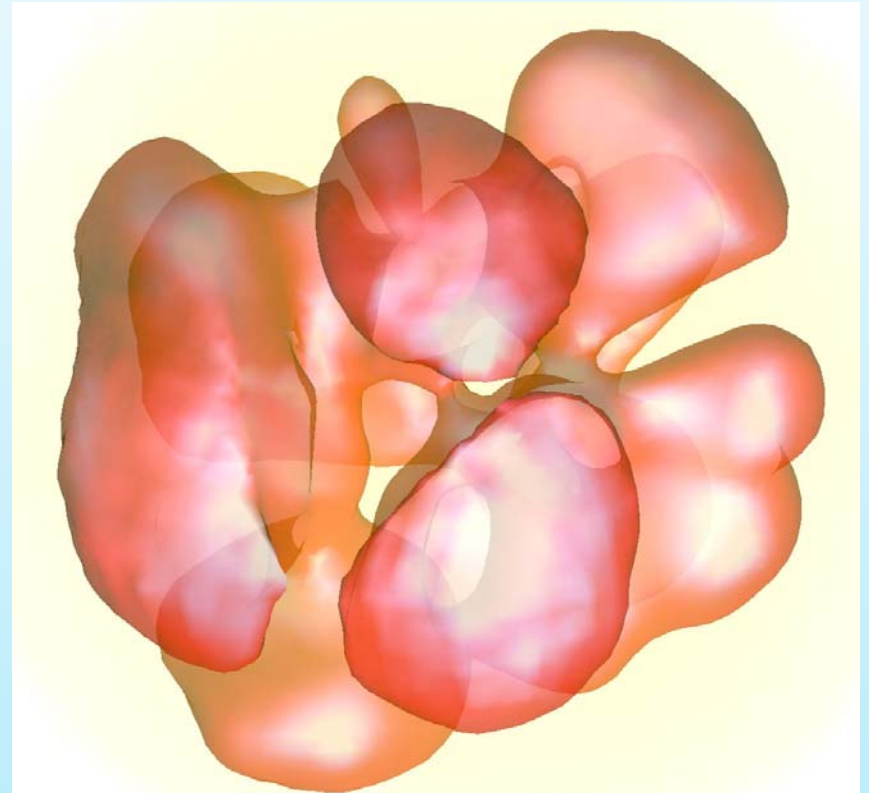
End

Simulation of Aquaporin Protein Inside a Cell (NSF & NIH)

Visualization shows transport of water molecules into cell.
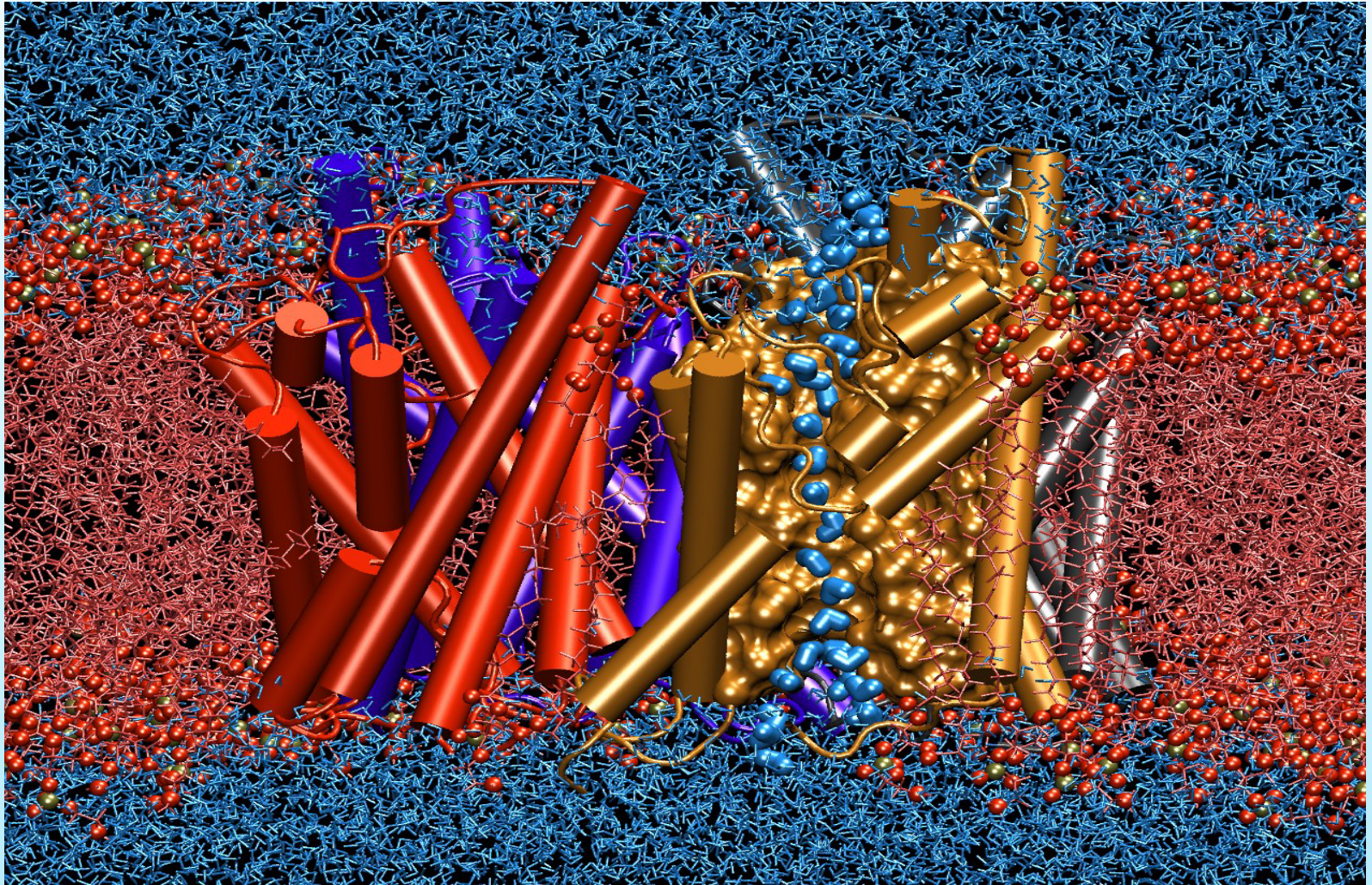
Environmental Modeling of the Chesapeake Bay (NOAA, EPA, DoD)

- **Image shows visualization of computed salinity in the Bay (red is high salinity.)**

- **South is up.**

- **Visualization is an important part of the model, because users may not be skilled computational scientists.**
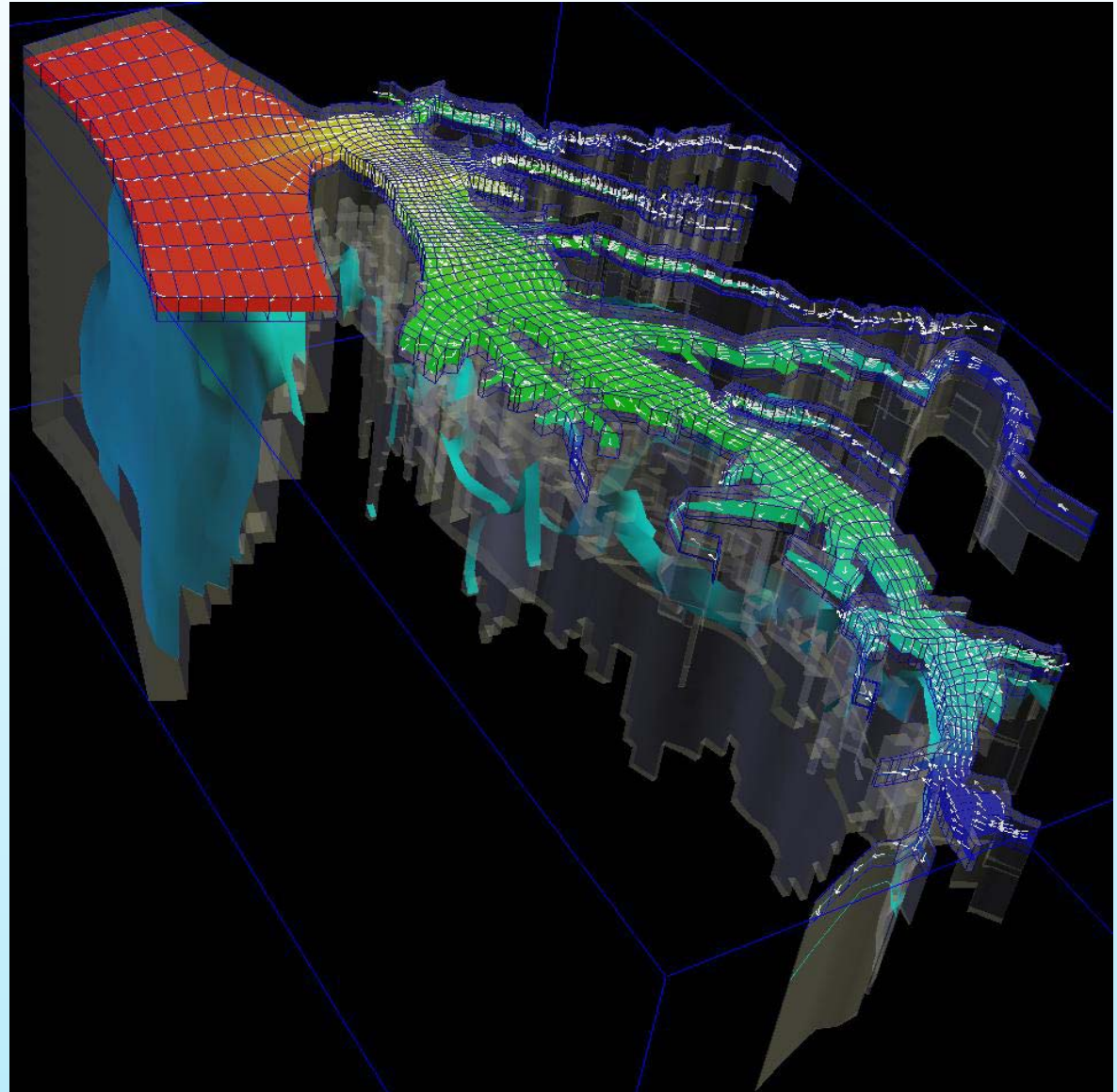
- **Large Scale Networking (LSN) Coordination Group**
    - Coordinates High Performance Research Network (HPRN) policy, interagency collaboration, and resource cooperation
    - Agency participants include: NIH, NSF, DARPA, DOE(SC), DOE(NNSA), ODDR&E, NIST, NASA, AHRQ, NOAA, NSA

- **Joint Engineering Team (JET)**
    - Provides engineering coordination among high performance research networks for transparency, interoperability, and sharing of resources.

- **Network Research Team (NRT)**
   - Provides coordination among high performance networking research programs to leverage resources and promote collaboration and exchange of information

- **Middleware and Grid Infrastructure Coordination (MAGIC)**
    - Promotes high performance research network middleware tools development, interoperability, research coordination, and infrastructure persistence

LSN Collaboration Research Areas

- Networking research into basic technologies, optical networking, services, and application
- Security
- Networking infrastructure for production, experimental, and research networks
- Network middleware and Grid
- Collaboration technologies
- Network monitoring and measurement
- Wireless, ad hoc, and sensornet capabilities
- Automated resource management
- Standards and specifications
- Crisis response and Critical Infrastructure Protection
- Education and training

- August 26-28: Workshop on the Blueprint for Future Science Middleware and Grid Research and Infrastructure
- March, 2003: New Directions in Scalable Cyber-Security in Large Scale Networks: Deployment Obstacles
- August 11-13, 2003: NSF Workshop on Security at Line Speed
- August 13-15, 2003: NSF Workshop on Cyber Trust PI Meeting and Research Agenda

- **NSF**
  - Grid Physics Network (GriPhyN)
  - Gemini: Connect 8.1 meter telescopes in Hawaii and Chile
  - AmericasPathway (AmPath)
  - STARLight
  - High Performance Wireless Research and Education Network (HPWREN)*

- **DOE**
  - Particle Physics Data Grid (PPDG)*
  - National Fusion Collaboratory (NFC)
  - Earth System Grid (ESG)
  - DOE Science Grid
  - Collaboratory for Multiscale Chemical Sciences (CMCS)
- **NASA**
  - Ground-Truthing Experiment*
  - NASA Information Power Grid

* Described in the this talk

- **NIST**
  - Agile Networking Infrastructures
  - Interoperability Testbed, software
- **ODDR&E**
  - Adaptive Protocols for Mobile Wireless Networks
  - Scalable Optical Networking for multilayer battlespace control
  - Mobil wireless scalable peer-to-peer networking
- **NIH**
  - Telemammography for the Next Generation Internet: National Digital Mammography Archive
  - Radiation Oncology Treatment Planning/Care Delivery Application
  - Remote, Real-time Simulation for Teaching Human Anatomy and Surgery
  - Mobile Telemedicine*

* *Described in this talk*
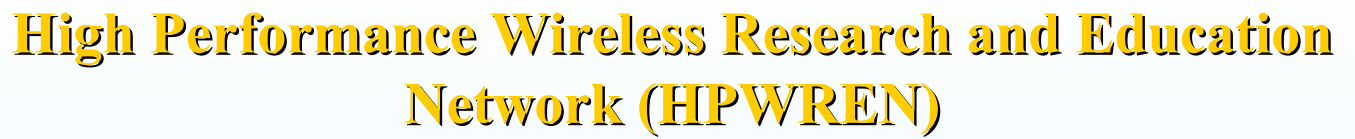
- **NSA**
  - Ultra high-speed Firewalls
  - Nonlinearity and transients in optical networks
  - Optical burst switch protocols
- **NOAA**
  - Near-real-time Doppler radar data support to weather modeling
  - Crisis response weather data support

NITRD

CMS — Compact Muon Solenoid at CERN

~PBytes/sec

Online System

~100 MBytes/sec

1 TIPS is approximately 25,000 SpecInt95 equivalents

Offline Processor Farm

~20 TIPS

~100 MBytes/sec

There is a "bunch crossing" every 25 nsecs.

There are 100 "triggers" per second

Each triggered event is ~1 MByte in size

Tier 0 — CERN Computer Centre

HPSS

~622 Mbits/sec or Air Freight (deprecated)

Tier 1

France Regional Centre — HPSS

Germany Regional Centre — HPSS

Italy Regional Centre — HPSS

FermiLab ~4 TIPS — HPSS

• • •

~622 Mbits/sec

Tier 2

Caltech ~1 TIPS

Tier2 Centre ~1 TIPS

Centre ~1 TIPS

Centre ~1 TIPS

Centre ~1 TIPS

~622 Mbits/sec
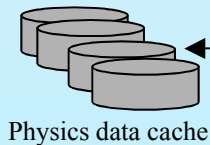
Institute ~0.25TIPS

Institute

Institute

Institute

Physics data cache

Physicists work on analysis "channels".

Each institute will have ~10 physicists working on one or more channels; data for these channels should be cached by the institute server

~1 MBytes/sec
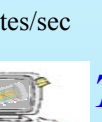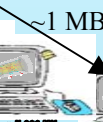
Tier 4

Physicist workstations

Image courtesy Harvey Newman, Caltech

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Ground-Truthing Experiment - FY 2003
Experiment Architecture

Ground-truthing experiment (summary):
Real-time Hyperion satellite imagery (data) is sent to a mass storage facility. Scientists at a remote (Utah) site upload ground spectra (data) to a second mass storage facility. The grid pulls data from both mass storage facilities and performs 16 simultaneous band ratio conversions on the data. Moments later the results from the grid are accessed by local scientists and sent straight to the remote science team. The results are used by the remote science team to locate and explore new critical compositions of interest. The process can be repeated as required to continue validation of the data set, or to converge on alternate geophysical areas of interest.

Commercial Ku Band Satellite

ARC Mass-storage facility

NASA NREN Backbone Network

Remote Sensing Satellite (Hyperion data set)

Field Scientist location (Near Vernal, UT)

NREN TES/STING Facility

Ground Instruments (GRC LPSM2)

GRC Mass-storage facility

GRC Grid (IPG Cluster)

Other Scientists On Internet

This geographical location is imaged by a satellite and measured by hand simultaneously

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NIH MOBILE TELEMEDICINE

- Optimizes   Treatment Options in the "Golden Hour"
- Initiates the Patient Record in the Ambulance
- Enhances the Efficiency of the ER
- Improves Patient Outcomes

Intuitive Physician's Interface

TeleBat Remote Ambulance 51 vers. 3.0 - Microsoft Internet Explorer

Address http://134.192.17.5/info.htm   File Edit Links

HR   88
BP   172/93 (155)
Sp02 96%
EtC02 100
RR   17

Name Doe, Mary Jane   Sex Female Age 37
Complains of Shortness of Breath;
Weakness on Left Side
Symptom Onset < 2 hours

TotalScore: 5   Frame

○ 1 LOC	0	184	
○ 2 LOC	1	270	
○ 3 LOC	0	306	
○ 4 Best Gaze	2	393	
○ 5 Facial Palsy	0	465	
● 6 Visual Fields	2	6	
○ 7 Arm Motor	0	0	
○ 8 Arm Ataxia	0	0	
○ 9 Leg Motor	0	0	
○ 10 Limb Ataxia	0	0	
○ 11 Sensory	0	0	
○ 12 Extinction	0	0	
○ 13 Dysarthria	0	0	
○ 14 BestLanguage	0	0	

Na	135
K	4.0
Cl	111
C02	30
Glu	98
HCT	41.2
PT	12.0
BUN	8.0
CR	0.9

Img 8/8: 6-27-1997 15:35:24:46

<< First < Prev PLAY Next > Last >>

AutoView: ON   Unviewed:0 .

Patient is slow to respond. Speech slurred...

Displayed Image 8/8: ' 6-27-1997 15:35:24:46' in 330 m   Local intranet zone

- Adjustable image compression quality (medium JPEG compression)

- Adjustable image size (320x240 24-bit images)

- About 5 kbps per phone line (4 phone lines)

- Resulting in diagnostic quality slowscan video images at about 2.5 seconds per image

Northrop Grumman, Fairfax, VA
University of Maryland in Baltimore, Baltimore, MD

NORTHROP GRUMMAN

NATIONAL LIBRARY OF MEDICINE

High Confidence Software and Systems

- **Research into software theories and methods to support software design and implementation "guaranteed" to meet specified design properties**
  - Reliability, security, safety, usability, confidentiality
- **Specifying such properties and verifying their attainment is currently ill-defined and difficult.**
- **Examples of applications:**
  - Certification of software for infusion pumps used in hospitals to deliver IV medications
  - Certification of FAA flight control systems before use
  - Certification of security of software in Common Criteria Program
- **High Confidence Software and Systems Research Needs:** **http://www.itrd.gov/pubs/hcss-research.pdf**

Software Design and Productivity

- **Develop methods and tools for software requirements, specification, design and implementation that will produce software on time, within cost, that meets functional requirements**

- **Recent problems with control software for military F/A-22 aircraft highlights importance of software design and productivity**

- **Workshop on New Visions for Software Design and Productivity: Research and Applications, published January, 2003**
    - http://www.itrd.gov/pubs/sdp_wrkshp_final.pdf

Human-Computer Interaction and Information Management

- **Human-Computer Interaction and Information Management as part of a continuum**

- **Closely related to DARPA work on cognitive systems**

- **Research topics include:**
  - How humans use data and information to control systems
  - Synergy between humans and computers in performing scientific exploration, model building and use, data mining, decision making

- **Issue of information preservation in on-line world**
  - Changes in formats, media and platform
  - Size of information collections

- **Report of Workshop on Research Needs will be published shortly**

For Further Information

Please contact us at:

nco@itrd.gov

Or visit us on the Web:

www.itrd.gov

Back Up

National Coordination Office (NCO) for Information Technology Research and Development (IT R&D)

Mission: *To formulate and promote Federal information technology research and development to meet national goals*

- NCO Director reports to the Director of the White House Office of Science Technology Policy (OSTP) and co-chairs the Interagency Working Group for IT R&D

- Coordinates planning, budget, and assessment activities for the Federal multi-agency NITRD Program

- Supports the six technical Coordinating Groups (CGs) that report to the Interagency Working Group
  - Research planning workshops, conferences, and meetings
  - Presentations, white papers, and reports
- Supports the President's Information Technology Advisory Committee

Publications

- Annual publication of the Supplement to the President's Budget also known as the "BLUE BOOK," describes the NITRD Program:

  http://www.itrd.gov/pubs/blue03/

- President's Information Technology Advisory Committee (PITAC) Reports:

  Transforming Access to Government Through Information Technology
  http://www.itrd.gov/pubs/pitac/pres-transgov-11sep00.pdf

  Developing Open Source Software to Advance High End Computing
  http://www.itrd.gov/pubs/pitac/pres-oss-11sep00.pdf

  Digital Libraries: Universal Access to Human Knowledge
  http://www.itrd.gov/pubs/pitac/pitac-dl-9feb01.pdf

  Transforming Health Care Through Information Technology
  http://www.itrd.gov/pubs/pitac/pitac-hc-9feb01.pdf

  Using Information Technology To Transform the Way We Learn
  http://www.itrd.gov/pubs/pitac/pitac-tl-9feb01.pdf

- Nuclear stockpile stewardship (multi-discipline physics models)
- Global and regional climate modeling
- Weather and ocean forecasting
- Geophysics (earthquakes, volcanoes, landslides, plate tectonics, magneto-dynamics)
- Astrophysics (star and galaxy dynamics)
- Aeronautics and aerospace design (air-frames, re-entry vehicles)
- Engineering design of ships, land vehicles, buildings
- Weapon designs and weapon effects
- Armor design
- Survivability/stealthiness design
- Signal and image processing
- Signals intelligence (e.g., cryptanalysis)
- Electromagnetics
- Molecular modeling for chemical risk assessment
- Biophysics (e.g., protein folding)
- Pharmacology
- Quantum chemistry
- Materials modeling and design (e.g., concrete)
- Quantum chromodynamics

Application	Science Accomplishment	Required Capability Multiple	Benefit to Nation
Signals Intelligence	Model, simulate, and exploit foreign codes, ciphers and complex communications systems.	1000	Supports U.S. policy makers, military commands and combat forces with information critical to national security, force protection and combat operations.
Directed Energy	To advance the directed energy systems design process out of the scientific research realm into the engineering design realm	1000	Ability to efficiently design next generation directed energy offensive and defensive weapon systems. Change the design process from years to days.
Signals Image Processing & Automatic Target Recognition	To replace electromagnetic scattering field tests of actual targets with numerical simulations of virtual targets	1000	Creates the ability to design more stealthy aircraft, ships, and ground systems and creates the ability to rapidly model new targets enabling more rapid adaptation of fielded weapon systems' ability to target new enemy weapon systems.
Integrate Modeling and Test of Weapon Systems	To model complex system interaction in real time with precision	1000	Creates the ability to replace many expensive, dangerous and time consuming ground tests with virtual tests resulting in lower test costs and more rapid development of weapon systems.
Climate Science	Resolve additional physical processes such as ocean eddies, land use patterns, and clouds in climate and weather prediction models.	1000	Provide U.S. policymakers with leading-edge scientific data to support policy decisions. Improve climate and weather prediction skill at timescales from minutes to decades.
Weather and Short-term Climate Prediction	Enable dynamical prediction of frequency and intensity of occurrence of hurricanes/typhoons and severe winter storms 90 days in advance.	1000	Provides critical support to deployed naval, air and land forces in local, regional and global combat environments. Lives saved and economic losses avoided due to better severe weather prediction.
Solid Earth Science	Dynamic earthquake forecasting with 5 year lead time.	100	Provide prioritized retrofit strategies. Reduced loss of life and property. Damage mitigation.
Space Science	Realistically simulate explosive events on the sun, the propagation of the energy and particles released in the event through the interplanetary medium, and their coupling to Earth's magnetosphere, ionosphere, and thermosphere.	1000	Provide decision makers (both civilian and military) with status and accurate predictions of space weather events on time scales of hours to days.
Subsurface Contamination Science	Simulate the fate and transport of radionuclides and organic contaminants in the subsurface.	1000	Predict contaminant movement in soils and ground water and provide a basis for developing innovative technologies to remediate contaminated soils and ground water.

National Security

Environment

Application	Science Accomplishment	Required Capability Multiple	Benefit to Nation
Magnetic Fusion Energy	Optimize balance between self-heating of plasma and heat leakage caused by electromagnetic turbulence.	100	Underpins U.S. decisions about future international fusion collaborations. Integrated simulations of burning plasma crucial for quantifying prospects for commercial fusion.
Combustion Science	Understand interactions between combustion and turbulent fluctuations in burning fluid.	100	Understand detonation dynamics (for example, engine knock) in combustion systems. Solve the "soot" problem in diesel engines.
Astrophysics	Realistically simulate the explosion of a supernova for the first time.	1000	Measure size and age of Universe and rate of expansion of Universe. Gain insight into inertial fusion processes.
Structural and Systems Biology	Simulations of enzyme catalysis, protein folding, and transport of ions through cell membranes.	1000	Ability to discover, design, and test pharmaceuticals for specific targets and to design and produce hydrogen and other energy feedstocks more efficiently.
Catalyst Science/ Nanoscale Science and Technology	Calculations of homogeneous and heterogeneous catalyst models in solution.	1000	Substantial reductions in energy costs and emissions associated with chemicals manufacturing and processing. Meeting federally mandated NOx levels in automotive emissions.
Nanoscale Science and Technology	Simulate the operation of nanoscale electronic devices of modest complexity.	1000	Takes miniaturization of electronic devices to a qualitatively new level enabling faster computers, drug delivery systems, and consumer and military electronics.
Nanoscale Science and Technology	Simulate and predict mechanical and magnetic properties of simple nanostructured materials.	1000	Enables the discovery and design of new advanced materials for a wide variety of applications potentially impacting a wide range of industries, including the high-tech industry that generated more than $900 billion in sales and accounted for 4 million jobs in 1999 and the $34 billion disk drive industry.

Energy and Physics

Biology and Nanoscience

- **Model is checked against measured data.**
- **Model has shown that approximately 1/4 of the nitrogen added to the Bay starts as air pollution, some from sources hundreds of miles from the Bay's watershed.**


Chesapeake Bay Bottom Dissolved Oxygen in Summer 1985
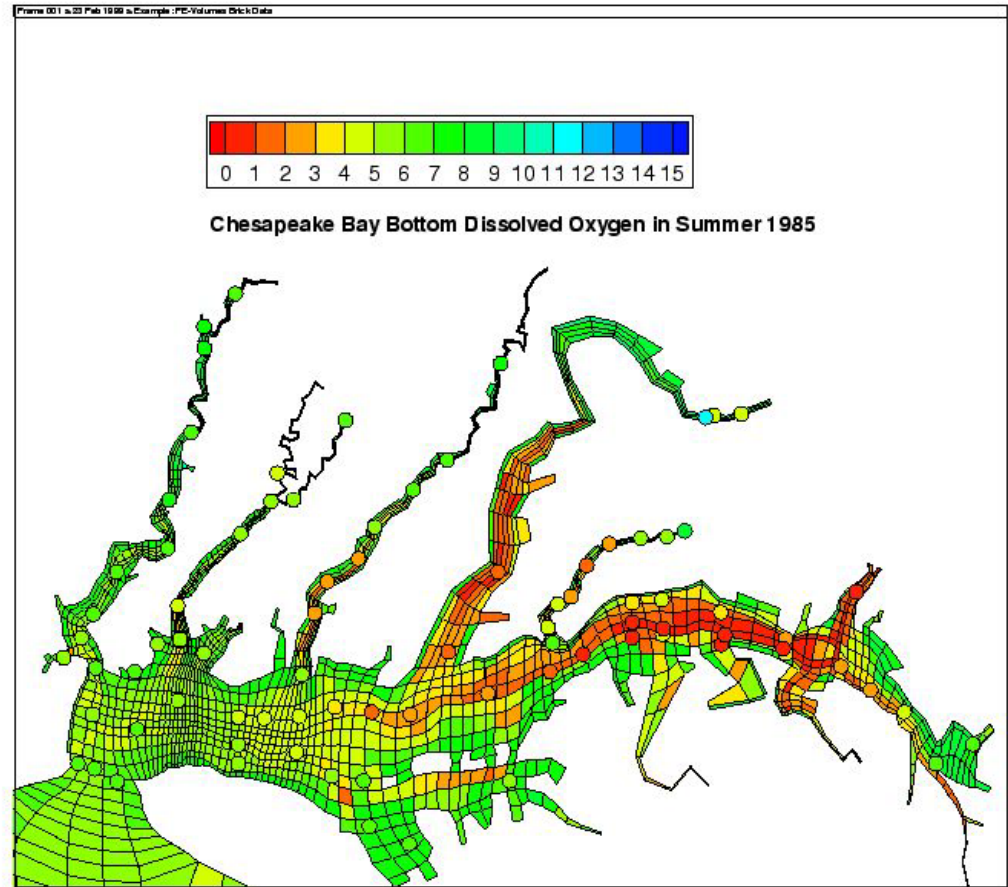
AmericasPath (AmPath) Service Area

THE GOAL OF THE NFC IS TO ADVANCE SCIENTIFIC UNDERSTANDING & INNOVATION IN FUSION RESEARCH

Collaboratory is required to advance fusion science: geographically diverse community (37 states, 3 large experiments), leading to 1 worldwide experiment

Fusion Collaboratory

- Fusion Research Center
- Large Fusion Experiment
- CSET Partner
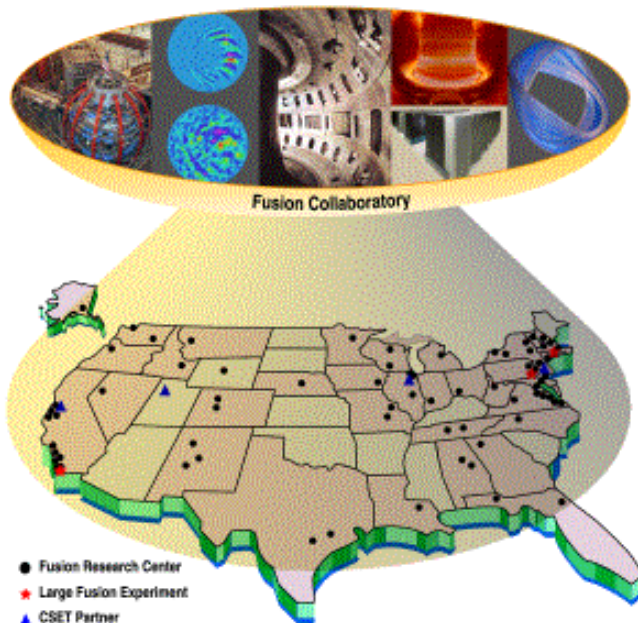
- Diverse team
  - ANL: DSL & FL
  - GA: DIII–D Fusion Lab
  - LBNL: Distributed Systems
  - MIT: C–Mod Fusion Lab
  - Princeton Computer Science
  - PPPL: NSTX Fusion Lab
  - U. of Utah: Scientific Comp. & Imaging
- Objective is to advance fusion science
  - Experimental facilities
  - Integrate experiment, theory, modeling
  - Create a common toolkit for services